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Working Paper Series

#2010-057

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Understanding causes and consequences of partnership mal-functioning

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February, 2010

Keywords: R&D Collaboration; Technological performance; Innovation; alliance failure
JEL classification: O31; O32

Acknowledgement
The empirical analysis for this paper has been performed using RA facility of Statistics Netherlands. We thank Gerhard Meinen for his assistance; the views expressed in this paper are those of the authors and do not necessarily reflect the policies of Statistics Netherlands. The authors are grateful for comments received from participants of the 2010 DRUID conference in London, two anonymous referees and the editor (Ben Martin).

UNU-MERIT Working Papers
ISSN 1871-9872

Maastricht Economic and social Research and training centre on Innovation and Technology, UNU-MERIT

UNU-MERIT Working Papers intend to disseminate preliminary results of research carried out at the Centre to stimulate discussion on the issues raised.

THE BUMPY ROAD OF TECHNOLOGY PARTNERSHIPS: UNDERSTANDING CAUSES AND CONSEQUENCES OF PARTNERSHIP MAL-FUNCTIONING

ABSTRACT

Research on technological partnerships has traditionally sought explanation of their high failure rates in partner characteristics and relationship features. This study introduces the notion of a ‘bumpy road’ in technology partnerships which refers to undesired outcomes such as ‘partnership mal-functioning’ and ‘instability’ to the degree to which innovation activities are hampered. We explain how firm-level strategies can reduce the probability of a ‘bumpy road’ in partnerships. We also assess the impact of this ‘bumpy road’ on innovative performance. We find that firms that excel in diversification of external activities (in terms of different types of partners) perform best. Moreover, a persistent product oriented innovation strategy geared at developing new products, new markets, or higher product quality will yield more stable partnership outcomes. Our results confirm that engagement in partnerships is beneficial for innovative performance. However, firms that experienced a ‘bumpy road’ in their technological partnerships have to pay a price in terms of a negative effect on their innovative performance.

(160 words)

INTRODUCTION

Failure is a frequent outcome of inter-firm partnering (Park and Ungson, 2001). High failure rates of 30 percent to 50 percent in partnerships are not an uncommon finding in the literature (e.g., Bleeke and Ernst, 1991; Harrigan, 1988; Killing, 1988). Especially technology partnerships, where firms exchange technology and jointly perform R&D in the context of complex intellectual property regimes, are inherently difficult to manage and hence this type of partnership is subject to the highest rates of failure (see e.g. Sadowski et al, 2005).

Partnerships can be unsuccessful for various reasons. Prior research sought explanations for this phenomenon from the perspective of several theoretical approaches (see Das and Teng, 2000a for a literature overview). Transaction cost economics stresses the pursuit of self-interest at the expense of the partner as well as the high costs of deterring such opportunistic behavior as a major cause of partnership instability (Williamson, 1985; Gulati, 1995). Game-theoretic approaches emphasize the role of uncertainty in predicting the intentions of partners and future payoffs (Parkhe, 1993a). The resource-based view suggests that inequality in resources that firms bring into a partnership gives rise to an eventual power imbalance between partners that can lead to a premature termination of their partnership (Bucklin and Sengupta, 1993; Das and Teng, 2000b; Osborn and Baughn, 1990). From the perspective of a strategic behavior approach, the literature points at the role of inter-firm rivalry and competition that increases the likelihood of partnership instability (Porter, 1985; 1990; Kogut, 1989).

The literature also indicates that partnerships are motivated by the need to share both risks and costs of R&D, to gain access to new technology and new markets, and to create synergetic effects (Hagedoorn, 1993). However, successful partnerships between competitors are expected to be rare because often achievement of these goals proves unrealistic, leading to a premature termination of a partnership (Porter, 1990). Partnerships with substantial overlap in core businesses, geographic markets, and functional skills are reported to have success rates of about 30 percent as competitors are inclined to maximize their own individual objectives rather than their collaborative interests. Moreover, managerial complexity of these joint activities induces a higher probability of partnership failure (Park and Ungson, 2001). In a partnership, two or more independent firms need to be coordinated and also the activities of the partnership have to be aligned with the parent firms' interests. This coordination may be cumbersome due to, for instance, cultural and organizational differences between partners turning partnership demise into a likely outcome (Parkhe, 1993b).

So far, the existing literature has seldom adhered to a uniform terminology when describing partnership outcomes. When assessing the positive performance of partnerships objective performance measures (e.g., sales growth, profitability, and return on assets) can be used or, alternatively, survey data can be employed where managers are asked directly to assess the performance of a partnership. For the assessment of less successful partnership outcomes, terms like 'failure', 'premature termination', 'dissolution' and 'instability' have been used interchangeably to indicate unfavorable results of a partnership (see Das and Teng, 200a; Park and Ungson, 2001 for overviews). In our study we take a combination of these two approaches as we consider both the functioning and the results of technology partnerships.

We employ a measure of firms experiencing a 'bumpy road' in their technology partnerships related to the notion of partnership instability as discussed by Das and Teng (2000a). We focus on firms that experienced a 'bumpy road' in their technology partnerships when unplanned outcomes such as stoppage, delay or abandonment of their joint innovation project(s) occurred. A somewhat similar approach has been recently adopted in Lhuillery and Pfister (2009). Our analysis deviates from their approach in a number of ways. First, we intentionally adopt a broader definition than simply premature partnership dissolution, by also analyzing those events when firms had difficulty-laden or even unproductive partnerships. We do so to explore a broader issue of what factors and firm strategies can reduce the probability of things going wrong in partnerships. Cooperation that results in a failure is only one instance of this broader mal-functioning of partnerships. Second, in the context of this broader perception of the mal-functioning of partnerships as their 'bumpy road', we investigate whether firms that employ a persistent innovation strategy geared at either reducing cost or developing new products face a lower probability of a such a 'bumpy road' in their technology partnerships. Third, we consider whether there is an inverse relationship between the diversity and breadth in the partnership portfolio of firms and the probability of their partnership mal-functioning. Finally, in our analysis we look at the effect that the 'bumpy road' in the technological partnerships of firms might have on their future innovative performance.

In the following, we study persistence in the overall firm's business strategy with respect to firm's innovative activities (product oriented vs. cost oriented) and in terms of firm's alliance strategy. Our approach follows the definition of persistence as 'state dependence' (e.g. Heckman, 1981), which in our context means that firms are studied from the perspective of both their past innovation activities/partnerships and their current continuation of these activities. A similar approach has been used to analyze persistence in profits (Mueller, 1977; McGahan and Porter, 2003), innovation (Roberts, 1999; Raymond et al, 2010) or other measures of firm performance such as Tobin's q (Villalonga, 2004). In these studies, persistence is also understood in terms of a relation between the 'current state' of a firm (in terms of its strategy or performance) and the 'past states' for the same dimension of its activities.

To test our hypotheses we employ three consecutive streams of data for the period 1994 – 2000 collected through the Community Innovation Survey (CIS). The CIS survey is organized by Eurostat and is aimed at collecting information on firms' innovating activities.

The survey covers both large R&D performing firms as well as smaller innovating firms with a limited number of technology partnerships.

The paper proceeds as follows. The next section presents the theoretical framework and derives hypotheses. We then describe the data, variables and methods. This is followed by a presentation of the results, the final section discusses these results and it presents the conclusions.

HYPOTHESES

Innovation strategy, partnership portfolio and a 'bumpy road'

Innovation activities relate to different objectives, such as a cost-oriented process innovation objective or a demand enhancing product innovation objective, and the pursuit of these different innovation objectives requires distinct firm capabilities. Such capabilities are further developed by routinely executing related activities persistently over an extended period of time (Nelson and Winter, 1982). Firm capabilities that are gradually accumulated through the repeated execution of similar activities may become a source of a firm's competitive advantage if these accumulated capabilities enable a firm to differentiate itself from its competitors (Barney, 1999; Diez-Vial, 2007; Hoetker, 2005).

We also note that innovations in products are inherently more uncertain than innovations that are cost related (Boer and During, 2001; Freeman and Soete, 1997). When, as in our paper, innovations in products entail the replacement of obsolete products, improvement of product quality, expanding the product range and extending the product market range, they have an explorative character. Such product innovation projects are rife with uncertainty and often the direction of this explorative search is unclear. Also, a possible partner for joint activities may be hard to identify. This uncertainty may be countered with a persistent product innovation strategy. If such a strategy is conducted repeatedly over time the firm gets a better notion of its technological possibilities and a better understanding of the future trends in consumer demands, which facilitates identification of future products and their attributes.

In the context of this persistent product innovation strategy, the goal of partnerships may be set with both higher clarity and higher commitment and this may help the stability of the individual partnership. When objectives are unclear at the start of a partnership this may lead to various changes made while this partnership is still ongoing. This is detrimental to the functioning of a technology partnership as demonstrated by Sadowski et al. (2005) who report that changes in the priorities and the strategy of firms, related to technology partnerships, is the most frequently mentioned reason for partnership termination (in nearly 53% of all cases). Also, a more persistent product innovation strategy may be helpful in determining proper partnership candidates for future projects. A more persistent strategy may assist identifying which competences a firm lacks and hence hint at which partners may fill the gaps in specific resources. Again this may aid in clearly identifying the objectives of partnerships and contribute to a lower likelihood of a malfunctioning partnership.

In sum, we expect that firms that persistently follow an innovation strategy, based on a product-focus, are less likely to encounter a bumpy road in their partnerships due to the accumulated and refined capabilities necessary for the execution of a strategy which leads to a lower probability of making mistakes in managing these partnerships. This suggests the following hypothesis:

Hypothesis 1: *Conducting a persistent innovation strategy, characterized by product focus, reduces the probability of a 'bumpy road' for a firm's technology partnerships.*

When innovation has a cost focus the goal is to increase efficiency in production processes, to reduce the cost of labor and materials, the use of energy, and to comply with government regulations on product standards and reduction of environmental impact. The nature of this type of process innovation is exploitative and in general the amount of uncertainty involved in exploitation is considerable but it is much less so than the uncertainty surrounding exploration. Still a persistent process innovation strategy based on cost focus may help in reducing the amount of uncertainty in terms of goal selection and partner choice, though the benefits are less than in the case of exploration. As a consequence we expect that:

Hypothesis 2: *Conducting a persistent innovation strategy, characterized by cost focus, reduces the probability of a 'bumpy road' for a firm's technology partnerships but the effect is less than that of a persistent strategy based on product focus.*

In recent years, the literature on partnership performance not only considers the impact of the innovation strategy of firms but it has also taken a closer look at the role of firm's 'partnership capabilities' in fostering partnership performance (e.g., Heimeriks, 2008). A firm's capability to transform its past collaboration experience into partnering routines is shown to significantly improve its future collaborative outcomes (Simonin, 1997). Such partnership capabilities and the accompanying collaborative know-how of a firm may, however, only gradually be built up by a firm through a deliberate learning process as it engages in multiple partnerships over time (Heimeriks and Duysters, 2007; Zollo and Winter, 2002). Firms that manage diverse partnership portfolios are expected to have developed superior coordination capabilities (Lavie and Miller, 2008) and therefore they are probably less prone to encounter a 'bumpy road'. We propose that the diversity of a firm's portfolio of partnerships is negatively related to a 'bumpy road'. This portfolio diversity, on the one hand, refers to the variety of different partnership types (with different partners such as customers, suppliers, competitors, universities, research centers, consultants, and with other firms in the same parent company) and, on the other hand, it refers to the number of partnerships of each type in the portfolio.

In addition, firms that have gained experience in managing such diverse partnership portfolios are exposed to a learning effect by sourcing information from a variety of contacts (Burt, 1992; Laursen and Salter, 2006; Leiponen and Hilfat, 2005). Extant research has shown that learning takes place through managing larger numbers of alliances but also through collaborations with different types of partners (e.g., Reuer et al., 2002). The learning effect achieved through the establishment of a diverse partnership portfolio can increase the efficiency of partnering strategies (Faems et al., 2005) and reduce the probability of a mal-functioning of partnerships. A broader range of collaborative links refines the organizational routines for cooperation and increases a firm's experience in managing inter-firm relationships (Das and Teng, 2002; Powell, Koput and Smith-Doerr, 1996).

Moreover, the establishment of multiple partnerships can benefit a company by facilitating access to a broader pool of technological opportunities and knowledge acquisition options from multiple sources and by allowing the exploitation of synergetic effects between different partnership strategies (Milgrom and Roberts, 1990; Belderbos et al., 2006). Previous research found that partnership portfolios of innovators are typically more diverse and internationally oriented compared to non-innovating and imitating firms (Duysters and Lokshin, 2007). Also, higher levels of portfolio diversity and internationalization improve the performance of firms (Lavie and Miller, 2008).

In sum, we expect an inverse relationship between diversity of a firm's partnership portfolio and the probability of partnership mal-functioning. The above leads to the following hypothesis:

Hypothesis 3*: The more diverse the partnership portfolio of a firm, the lower the likelihood of a 'bumpy road' for its technology partnerships.*

The effect of a 'bumpy road' on innovative performance

If we are to find that, under certain conditions, there is a higher likelihood of firms to face more or less of a 'bumpy road' with their technology partnerships, an interesting question that remains is: does it matter, do 'bumpy roads' in technology partnerships lead to lower innovative performance? In general, technology collaboration has been shown to be important for a firm's innovation success (Hagedoorn, 1993; 2002; Un, Cuervo-Cazurra, Asakawa, 2008; Rowley et al., 2000; Song and di Benedetto, 2008). The knowledge-based perspective on partnerships posits that formation of technology partnerships is an essential mechanism that a firm uses to access knowledge it lacks (Spender and Grant, 1996; Eisenhardt and Santos, 2002; Spender, 2007). However, the process of gaining knowledge across firm's boundaries is complex and prone with pitfalls (Kogut and Zander, 1992) and when this knowledge acquisition through partnerships strands, or when a 'non-learning' outcome occurs, this will contribute to the partnership demise (Doz, 1996).

So, when partnerships are crucial to a firm, partnership mal-functioning will be harmful for its ability to bring innovations into the market. Partnership mal-functioning will have negative consequences for the innovation process of a firm as it will delay or complicate the acquisition of knowledge necessary for the continuation of a firm's innovation cycle. Hence, a 'bumpy road' will have negative consequences for a firm's innovative performance when a particular product, process or technology is delayed or is not altogether developed as a result of unsuccessful collaboration. The above arguments suggest that a 'bumpy road' in technological partnerships will have a negative impact on firm's future innovative performance:

Hypothesis 4: *The experience of a 'bumpy road' in a firm's technological partnerships is negatively related to its future innovative performance.*

METHODS

Sample and descriptive statistics

The data for our study come from three consecutive Community Innovation Surveys (CIS2, CIS2.5 and CIS3). These bi-annual surveys were conducted in 1996, 1998 and 2000 by Statistics Netherlands (CBS) and concern the innovation and partnership activities of Dutch firms in the period from 1994 to 2000. The data collection methodology and the questionnaires are described in the OECD Oslo Manual (OECD, 1997). The reliability of the CIS was tested by Eurostat which uses the surveys to collect official data on innovation activities of firms in the EU. The CIS surveys are sent to all large firms and to a random sample of firms with 10 or more employees and they cover all manufacturing and service sectors at the ISIC 3 level. The Dutch CIS have a response rate above 70%. We merged the surveys using the unique enterprise id number.

The bi-annual CIS questionnaires are suitable to study the determinants of firms' technology cooperative strategies since partnerships typically last about two years (e.g., Lavie and Miller, 2008), while an average R&D project duration has been estimated at one to two years (e.g., Pakes and Griliches, 1984; Pakes and Schankerman, 1984).

The CIS questionnaire has a multi-layer structure. Only those firms that report to be engaged in innovative activities (e.g. introducing new products, and/or new processes and/or organizational innovations) are asked to complete the entire questionnaire. In our analysis we focus on innovating firms only. The CIS question used to derive our focal partnership measure is formulated as follows: "Did your enterprise have any (if yes indicate the type of organization) partnership arrangements on innovation activities with some other enterprises or institutions in 1996-1998 (in case of CIS2 in 1994-1996)". We also relied on the following survey question to measure whether those innovating firms that reported partnerships experienced a 'bumpy road' in their partnership arrangements: "Did your enterprise have any innovation projects that were a) seriously delayed b) were stopped c) did not begin in 1996 -

1998 due to difficulties in working together in partnerships [that you indicated to be engaged in]?" The parts a), b) and c) in this question are not exclusive and some firms in our sample ticked all three responses.

The total survey sample of CIS 2 is 10664 firms from which 2291 firms are classified as product innovators and 1511 firms had one or more partnerships with one or more of the seven types of partners which include such types as customers, suppliers, competitors, universities, research centers, firms belonging to own concern, or consultants. The total survey sample of CIS 2.5 is 13465 firms from which 2649 are product innovators and 1700 firms had one or more partnership links. Partnerships with competitors, which has been the focus of much of the partnership literature, is not the most frequently adopted strategy (687 firms). Cooperation with customers (903) and suppliers (942) are more frequently mentioned, as well as links within the own concern (840). Among the 1700 innovating firms that had at least one of these seven types of partnerships, 162 (10%) had their innovation projects stopped, delayed or not started. The total survey sample of CIS 3 is 10750 firms from which 1777 introduced new to the market products and 1212 firms had one or more partnership links.

Due to missing data on some of the variables we end up with an estimation sample of 2839 firms for the merged surveys in our bumpy road model, 629 of which had one or more partnership links. Among these firms, 131 have reported to experience a 'bumpy road'. Cooperation with competitors is most likely to end in a 'bumpy road' outcome, while this probability is lowest for the vertical type of cooperation with customers and suppliers (see Appendix A).

Our analysis of how a 'bumpy road' affects innovative performance is based upon an estimation sample of 944 firms which includes firms with no partnerships**.** The 'performance equation' sample is somewhat smaller compared to the 'bumpy road' model sample because we lose some observations when we link survey in year t (1998/1996) with the year t+1 survey (2000/1998).

Table 1 describes the way the variables we use in our study are constructed and it lists the descriptive statistics. Correlations between the variables used in the estimations of the 'bumpy road' model and the performance model are given in Appendix B, Tables B1 and B2, accordingly.

[TABLE 1 IS ABOUT HERE]

To test our hypotheses we estimate two models: a model in which we explain the probability of a firm to experience a 'bumpy road' in its technological partnerships and an innovation performance model in which we test whether a 'bumpy road' has a subsequent impact on a firm's innovative performance. Below we explain how we measure the variables used in the estimation.

Dependent variables in the 'bumpy road' equation

Our dependent variable in the 'bumpy road' equation is a binary (yes/no) indicator of a 'bumpy road' experienced by a firm in technology partnerships during 1996 - 1998. In a recent study of partnership portfolios and firm performance Lavie and Miller (2008) report that an average duration of a technology partnership is 1.82 years. Cooperation viewed by partners as performing unsuccessfully can last much shorter (Porter, 1987). Our indicator of a 'bumpy road' variable takes the value of one in case a firm reported that it had some kind of instability in its partnership agreements, as suggested by Das and Teng (2000a). In our dataset such partnership instability is reflected if innovation project(s) are stopped, seriously delayed or not started altogether due to mal-functioning of partnerships in which the firm was engaged. Arguably, only for those firms that indicated that (some of) their innovation projects were prematurely terminated, i.e. stopped, due to partnerships, there is an instance of unambiguous partnership failure. Other responses are less clear-cut. For example, a delay in projects could be experienced because of a more difficult nature of certain collaborative projects that are eventually brought to a successful end. In our main model we intentionally use a broader indicator than simply premature partnership dissolution by also including those firms that had less successful partnerships. As such we seek to explore a broader issue of what factors and firm strategies can reduce the probability of mal-functioning of partnerships. Cooperation that results in a failure is only one example of this mal-functioning.

Only firms engaged in cooperation can experience partnership mal-functioning. Therefore, we have a sample selection issue in our model which we resolve by formulating a selection equation in which we model a firm's decision to start technology collaboration. The dependent variable in our selection equation is also a binary indicator that takes a value one if a firm reports to be engaged in collaboration with one or more (types) of partners during the 1996 - 1998 period. Both dependent variables in the equation for the propensity to engage in cooperation and in the equation for the probability of partnership mal-functioning are the measures taken from the CIS 2.5 (year t) survey. We estimate the (first-stage) selection and the main 'bumpy road' equations via a full maximum likelihood estimation procedure (e.g., Van de Ven and Van Praag, 1981).

Independent variables in the 'bumpy road' equation

Persistence in innovation strategies. In our view, if firms develop a propensity for a particular type of activity, then such behavior should be called a persistent strategy. In this light, operationalization of "persistent strategy" can be achieved by multiplication of states. Suppose for instance that there are two firms. Firm I conducts a persistent strategy quantified by H in two consecutive years and firm II undertakes a persistent strategy labeled L in two consecutive years. Multiplication of states identifies firm I as a persistent H firm and firm II as a persistent L firm (H*H versus L*L). Taking the difference of the states would indicate that both firms conduct a “no change” strategy (i.e H-H=0 and L-L=0). Hence we adopt the first method.

To test the first two hypotheses we include two variables, derived from the CIS questions that ask firms about their innovation strategies. These measures reflect firm’s priorities in their innovation activities and relate either to product focus or cost focus. We make these variables operational using the information in CIS on the importance of demand-enhancing and cost-saving objectives for a firm’s innovations. The variable *product focus* is constructed as a sum of scores on the importance of four categories of firm’s objectives, related to new products (replacement of obsolete products, improvement of product quality, expanding product range, extending product markets). The variable *cost focus* is constructed as the sum of scores on the importance of six categories of cost-saving objectives for the firm’s innovations (increase in efficiency in production processes; reduction of cost of labor; cost of materials; and reduction in the use of energy; compliance with the government regulations on product standards; reduction of environmental impact). We construct these variables for 1996 and 1998 and our persistency measure is a product of the corresponding 1996 and 1998 variables.

Partnership portfolio diversity. We consider a partnership portfolio that spans different partnerships types, which include industry partners (competitors) as well as non-industry partners (customers, suppliers, universities, research centers, consultants and own concern allied firms). For each firm i in our sample we calculate a simple measure

$r_{i,m} = \frac{\sum_{n=1}^{5} x_{m,n}}{\sum_{m=1}^{7}\sum_{n=1}^{5} x_{m,n}}$ ($m = 1,...,7; n = 1,...,5)$, where each, $x_{m,n}$ can take the value of zero or one, *m* counts the seven different partnership ties and *n* counts the five regions distinguished in this paper (domestic, EU, US, Japan, or elsewhere). In the expression for $r_{i,m}$ the numerator $\sum_{n=1}^{5} x_{m,n}$ sums over links of the same type reported by a firm and takes a minimum value of zero (when a firm has zero partnerships with a particular type of partner) and a maximum value of five when a firm has partnerships in each of the five regions. The double sum in the denominator sums over all types of links. The ratio $r_{i,m}$ gives the proportion of each link-type *m* out of the total number of link-types for each firm. Our measure of portfolio diversity is then expressed as $d_i = 1 - \sum_{m=1}^{7} r_{i,m}^2$. This measure, which is bounded between zero and unity has been used in the literature to measure partnership portfolio diversity (e.g., Powell et al., 1996). We construct the partnership portfolio diversity measure from the data for both surveys in 1996 and in 1998.

Independent control variables in the 'bumpy road' equation

Obviously, firms differ in many aspects, including their innovativeness. Given such differences, we expect that firms that establish themselves at the innovation frontier will enjoy a superior reputation vis-à-vis their rivals that are less successful innovators. Extant research suggests that a positive technological reputation of firms may help lessen the likelihood of frictions between partners and ensure a robust relationship and positive outcomes of a partnership (e.g., Saxton, 1997; Dollinger, Golden, Saxton, 1997). Following conventional practice we construct '*R&D intensity*' as the total internal innovation expenditures as percentage of sales. By using the intensity measure rather than an absolute value, we counter scale effects.

Firm strategies are more likely to result in successful outcomes if firms stick to certain routines that remain similar over an extended period of time (Nelson and Winter, 1982). Following a strategy that reflects a systematic trajectory of actions is more likely to bring success to firms because it involves decisions similar to those that managers have made in the past. Systematic strategies are more likely to succeed to the extent that they are anchored in organizational know-how and rest on a company's employment of its core skills (Pennings, Barkema and Douma, 1994). A firm that has a consistent structural preference for particular partners has probably accumulated experience in dealing with these partners. By engaging in repeated ties with the same kind of partner a firm will learn to fine-tune its reactions to similar problems it encountered with similar partners or partners of the same type (e.g., Kale, Dyer, and Singh 2002). Furthermore, a systematic trajectory of repeated ties with the same type of partner may be different from non-systematic strategies in that the former may have such features as trust, reciprocity and superior information exchange between partners and hence will lead to a lower probability of a 'bumpy road'.

To summarize, firms that have a consistent structural preference for one type of partner are less likely to encounter a bumpy road in partnerships due to first-hand experience in dealing with a particular type of partner and because of the reduced probability of opportunistic behavior (Gulati, 1995). We operationalize '*persistence in partnering strategies*' as follows. By combining the 1994-1996 and 1996-1998 surveys we are able to construct a 'persistent-same-type' technology collaborator measure. A 'persistent-same-type' collaborator is a firm that had partnerships with a respective vertical (customers, suppliers or both) or horizontal (firms in the same industry) type of partner in both two-year time periods.

Previous literature identified various environmental conditions as a possible cause for partnership instability (e.g., Kogut, 1989; Park and Russo, 1996; Park and Ungson, 2001). Following the discussion in e.g., Howells (2002) we created an '*infrastructure*' dummy taking the value of one, indicating the presence of partnerships with research centers and consultants to account for firm's cooperative activities with non-industry partners, and zero otherwise.

We also included controls for inter-industry variation taking account of, for example, differences in riskiness of innovation projects by including aggregated '*industry dummies*'. We distinguish between high tech, medium tech, low-medium tech and low tech industries. We used an OECD classification to assign ISIC-3 industries into these four classes.

The intensity of competition within an industry could be a source of a higher rate of partnership mal-functioning (Park and Ungson, 2001; Das and Teng, 2000). We control for this by including a '*competition index*' variable, which is constructed at the 2-digit industry level as a sum of scores on six dimensions corresponding to Porter's taxonomy of competitive forces (perceived internal rivalry, supplier and customer power, perceived threat of entry and substitute products and institutional influence). Each of the dimensions is measured through a series of questions in a structured questionnaire administered by EIM (an institute that conducts business and policy research in the Netherlands). Reliability of the dimensions and the questionnaire are given by Kemp, Mosselman, and van Witteloostuijn (2004).

Researchers usually control for variations in industry conditions by including industry dummies in the regressions. Because we cannot use the competition variable simultaneously with the industry dummies due to perfect multicollinearity, we estimate two specifications, one with the competition index and one with the industry dummies without the index.

Finally, we control for '*firm size*', which is measured as the logarithm of the number of employees. We expect a negative relation between size and 'bumpy road'. Previous literature argues that larger firms are less vulnerable to exploitation in collaborative arrangements that endangers the partnership stability than smaller firms (e.g. Osborn and Baughn, 1990; Park and Ungson, 1997).

Explanatory variables in the propensity to cooperate equation

We draw on the industrial organization and strategic management literatures to specify our selection equation which explains firms' propensity to engage in technology partnering. Previous contributions argue that incoming spillovers, i.e. voluntary exchange of knowledge in cooperative arrangements, generally increase a firm's incentives to collaborate (e.g., Abramovsky et al., 2008; Belderbos et al., 2004). In our model we include a measure (taken in period t-1) of the importance of information received from industry partners (customers, suppliers, competitors) for a firm’s innovative activities to control for source-specific incoming knowledge transfers. Following Cassiman and Veugelers (2002) we also include a similar measure constructed as a sum of scores on the importance of information obtained from patents, conferences, and publications for a firm’s innovative process to control for public information sourcing. In addition, we add R&D intensity as a measure of absorptive capacity that allows a firm to effectively capture incoming knowledge flows (Cohen and Levinthal, 1989).

Recent work on technology partnering suggests that firms can attempt to manage knowledge transfers by exploiting incoming knowledge spillovers through partnerships and at the same time limit the information outflows (e.g., Amir et al., 2003; Cassiman et al., 2002). Availability and effectiveness of means to protect innovations has been found to be a positive determinant of a firms’ decision to form external collaborative agreements (Ahuja, 2000; Cassiman and Veugelers, 2002). To partly control for this effect, we include a dummy variable which takes the value one if a firm has patents, else zero.

Prior empirical research suggests that firm size and the propensity to form partnerships are correlated (e.g., Belderbos et al., 2006; Harrigan, 1988). Larger firms have more abundant resources and may find it easier to manage multiple technology partnerships. We include firm size measured as the logarithm of the number of employees in the propensity to form partnerships equation. We also control for whether a firm is domestic or multinational and for whether it is part of a larger corporate group by including corresponding dummy variables.

Finally, informed by the previous literature on the motives behind technology partnerships (Hagedoorn, 1993; 2002; Das and Teng, 1998) we include three firm-specific measures related to cost and risk of innovation as well as organizational rigidities that capture factors that hamper a firm’s innovation process, potentially inducing it to seek partnerships. See also table 1 for more details on these variables.

Dependent variable in the innovative performance equation

In order to test the fourth hypothesis pertaining to the effect of the ‘bumpy road’ on a firm’s performance we estimate a model in which the dependent variable is the share of new product sales in turnover. These new products were new to the market and were introduced by a firm in the period $t+1$ (i.e. in 1998 to 2000). Product novelty can be defined on the basis of the technological significance of the invention or its market relevance (Trajtenberg, 1990). CIS uses the latter approach. We pass this variable through a logistic transformation prior to the estimation.

Explanatory variables in the innovative performance equation

The explanatory variables in the performance equation are the occurrence of a ‘bumpy road’, presence of technology partnerships, R&D intensity, firm size, a dummy controlling for whether a firm is part of a domestic group or foreign multinational (cf. Belderbos et al., 2004). We also included the variable public incoming spillovers (cf. Cassiman and Veugelers, 2002).

A vector X contains industry dummies indicating whether a firm operates in a high tech, medium tech, low-medium tech or low tech industry and firm location dummies (at the province level). As argued in the above, we expect a negative impact of a ‘bumpy road’ on a firm’s innovative performance. We further expect a positive impact of technological partnering on performance and a positive impact of R&D input on innovative performance.

The ‘bumpy road’ variable in the performance equation is potentially endogenous because, for instance, unobserved managerial qualities may affect both the occurrence of a bumpy road and the innovative performance of a firm. Therefore, instead of the actual values, we use the fitted (predicted) values of ‘bumpy road’, $\hat{Y}_i$ which we obtain after the maximum likelihood estimation of equations (1) and (2) (see below).

Modeling approach

In order to analyze the determinants of a 'bumpy road' we jointly estimate the firm's decision to engage in partnerships and the probability that a 'bumpy road' will occur when such partnerships are formed. Only those firms that are engaged in cooperation can experience partnership mal-functioning. Therefore, we have a sample selection issue in our model. To take this into account we estimate a Heckman probit model with selection. The main equation in our model describes the probability that one (or more) of a firm's partnerships will mal-function. The selection equation explains the decision of a firm to engage in cooperation. Both equations are estimated simultaneously via a maximum likelihood estimation method. The equations are given by:

$$\begin{aligned}
Y_i = \alpha + \beta_1 Prod_focus_i + \beta_2 Cost_focus_i + \beta_3 Div_i + \beta_4 Div_{i,t-1} + \\
+ \beta_5 Rdint_i + \beta_6 Coop_vert_i + \beta_7 Coop_hor_i + \beta_8 Coop_mix_i + \\
+ \beta_9 Size_i + \beta_{10} Infra_i + \beta_{11} Univ_i + \beta_{12} Comp_i + \kappa X_i + \varepsilon_i
\end{aligned} \tag{1}$$

For an explanation of these variable names we refer to Table 1. We observe in (1) only a binary outcome:

$Bumpyroad_i = 1$ if $Y_i > 0$, and is zero otherwise.

The latent variable Y_i, partnership mal-functioning, is not always observed. The dependent variable for firm i is observed if cooperation takes place (selection equation) which is the case if in our model:

$$\begin{aligned}
Z_i = (a + \varphi_1 Spil_i + \varphi_2 Pubinf_i + \varphi_3 Size_i + \varphi_4 Rdint_i + \varphi_5 Domfirm_i + \\
+ \varphi_6 Domgroup_i + \varphi_7 Patent_i + \sum_{n=8}^{10} \phi_n Hamp_{n,i} + \zeta X_i + u_i) > 0
\end{aligned} \tag{2}$$

Hence, the dependent variable in the selection equation indicating the occurrence of cooperation is

$Cooperation_i = 1$ if $Z_i > 0$, and is zero otherwise.

Both error terms in equations (1) and (2), ε_i and u_i, are assumed to be normally distributed and are correlated, with correlation parameter $\rho \neq 0$.

To test whether a 'bumpy road' has an impact on a firm's innovative performance, we can augment the system of equations (1) and (2) with the following performance equation:

$$NewSales_i = a + \zeta_1 \hat{Y}_i + \zeta_2 Cooperation_i + \zeta_3 Rdint_i + \zeta_3 Size_i + \zeta_4 Domgroup_i + \zeta_5 MNE_i + \\ + \zeta_6 Spil_i + \psi X_i + \upsilon_i \qquad (3)$$

The dependent variable in our innovative performance equation is the share of new products in turnover which were new to the market and introduced by a firm in the period $t+1$ (i.e. in 1998 to 2000).

RESULTS

Table 2 reports the results from the selection equation (2), which explains firms' propensity to engage in technology partnerships. Firms are more likely to engage in technology partnering when they expect large incoming knowledge flows from the industry partners ($\varphi_1 = 0.05$, $p<0.01$). On the other hand, information from the public sources has little effect on such a propensity. Larger firms are more likely to engage in cooperation ($\varphi_3 = 0.20$, $p<0.01$), confirming earlier results that found that the size of companies is a significant predictor to form partnerships due to more abundant resources of larger firms (Cohen and Klepper, 1996; Harrigan, 1988). More R&D intensive firms are also more likely to form partnerships ($\varphi_4 = 0.01$, $p<0.01$). Firms' R&D spending increases their absorptive capacity and ability to assimilate external knowledge from partners (Cohen and Levinthal, 1990; Mowery and Oxley, 1995). Firms that experience bottlenecks caused by financial risk in their R&D projects and uncertain markets are more likely to seek external partners ($\varphi_{10} = 0.09$, $p<0.01$). However, the coefficients for the variables that measure other types of constraints such as lack of financial resources and organization rigidities are, although positive, not significant at the conventional levels. Our patent variable, which we used as a proxy for IPR protection, is also positive and significant (φ_7 = 0.26, p<0.01), confirming earlier findings that the effectiveness of means to protect innovations from imitators has a positive influence on firms decision to engage in partnerships (Ahuja, 2000).

[TABLE 2 IS ABOUT HERE]

[TABLE 3 IS ABOUT HERE]

Table 3 reports the results from the 'bumpy road' equation (1). Firms that persistently pursue a product-oriented innovation strategy are less likely to encounter a 'bumpy road'. The coefficient on this variable is negative and significant (β_1 = -0.02, p<0.01), supporting Hypothesis 1.[1] We find the coefficient on the variable indicating whether firms conduct a persistent cost focus innovation strategy to be insignificant. This result rejects hypothesis 2. However, it is in line with our expectation that the effect of this variable should be less pronounced than that of the persistent product innovation strategy. Apparently persistency of a cost oriented innovation strategy is not required to counter uncertainty along this dimension. The results also indicate that increasing technology partnership diversity has a

[1] Jointly pursuing a product and cost oriented strategy may affect the chance of a 'bumpy road' as well. We have tried a number of interaction terms to account for this. For instance, we have added a dummy equal to one if a firm scores high (above average) on the Likert scale for the objectives relating to both product and cost focus, else zero. The sign of such a variable is positive as expected but not significant and its inclusion does not affect our other findings.

negative impact on the probability of experiencing a 'bumpy road.'[2] The coefficient on the partnership diversity measure taken in 1996 (t-1) period is (β_4 = -0.41, p<0.01), supporting Hypothesis 3. [3] We note that the coefficient on a con-current diversity variable is not significant.[4]

For the control variables, we observe that the probability of a 'bumpy road' is lower for innovative firms. The coefficient on the R&D intensity measure is negative and statistically significant (β_5 = -0.04, p<0.01). Pursuing a consistent strategy in technology collaboration by forming partnerships with the same type of partners can help reduce the

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[2] To test for non-linear effects of diversity we included diversity (t) squared and diversity (t-1) squared. These variables are not significant at the conventional levels.

[3] We also experimented with a different diversity variable, constructed as before but now using knowledge sources (that firms report to be important in their innovation activities) instead of actual partnerships. When constructing this alternative diversity measure we experimented by using only industry partners (customer, supplier, competitor) in constructing it, alternatively using only those responses that are rated 'important' or 'very important'. This variable has a negative coefficient, as expected, but not significantly different from zero at any conventional level. It did not affect other results in the model. This would suggest that diversity in experience of actual partnerships, not simply in sourcing knowledge, is necessary to reduce the probability of a 'bumpy road'.

[4] We note that identification of the parameter measuring the effect of this variable is not hampered by multicollinearity. The coefficient of correlation between the diversity variables in 1996 and 1998 is only about 0.2. Furthermore, if we drop the 1996 diversity variable form the model, then the 1998 variable remains insignificant.

probability of a ‘bumpy road.’[5] The coefficients on our persistent partnerships variables are all negative, however only the vertical type is statistically significant (β_6 = -0.26, p<0.01).[6] Among the other control variables, firm size and a measure of competition intensity are statistically significant. The probability of a ‘bumpy road’ decreases with firm size.[7] This last result is in line with studies that argued that smaller firms are more vulnerable to exploitation in partnerships endangering their stability (e.g., Osborn and Baughn, 1990; Park and Ungson, 1997). In the specification where we include an industry competition index, this variable is

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[5] We also estimated the model in which we include variables indicating the presence of vertical, horizontal or mixed ties in 1996 together with the variable accounting for the persistence of such relationships. When both variables are present in the model none of the variables accounting for these relationships are significant due to identification problems caused by multicollinearity. If we do not include the variables accounting for persistent ties then only the variable accounting for a vertical tie in 1996 becomes negative and significant. However, it is estimated much less precisely than the variable accounting for persistent vertical ties and hence our preferred model includes the persistency variables.

[6] We also tested the differentiated impact between customer and supplier variables by separately estimating coefficients on ‘persistent customer collaboration’ and ‘persistent supplier collaboration’, which were both negative (-0.12 and -0.25, accordingly), as expected, however only ‘persistent supplier collaboration’ is significant (p=0.02). These results suggest that especially conducting strategy of persistently allying with suppliers can lead to reduced probabilities of experiencing a ‘bumpy road’.

[7] A large firm might be able to manage more efficiently its partnership portfolio. We tested this formally by including additional interaction terms between the firm size and our diversity measure. Neither of the two interaction terms turns out to be statistically significant. In fact, the fit of the model has declined when the interaction terms are included.

positive and significant (β_{12} = 0.06, p<0.01). This suggests that an increase in competition could lead to a higher probability of partnership failure (cf. Park and Ungson, 2001).[8]

Table 4 reports the results from the performance equation (3). These results confirm Hypothesis 4. We find a negative and significant impact of the 'bumpy road' on a firm's innovative performance (coefficient $\zeta_1 < 0$, p<0.05). This result suggests that those firms that experience a 'bumpy road' in their technology partnerships will introduce fewer new products to the market. On the other hand, we find a positive impact of technology partnering on performance (coefficient $\zeta_2 > 0$, p<0.01), suggesting that firms that form partnerships outperform those firms that do not. Among the control variables, we find a positive impact of R&D input on innovative performance ($\zeta_3 > 0$, p<0.1), while the variable firm size is not statistically significant.[9]

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[8] Our statistical model describes the probability of experiencing a 'bumpy road' and is equal to one minus the probability of no 'bumpy road', which equals one minus the probability of no 'bumpy road' for a single partnership in the power n, where n is the number of partners. In short, the probability of experiencing a 'bumpy road' is a function of n, the number of partnership links. Observing a 'bumpy road' with one of the partners is then more likely with a higher number of partnerships. We have also estimated the model including a variable measuring the number of different partnership types to control for the possibility that a simple increase in the number of links can raise the probability that things go wrong in one of them. To control for this we included a simple count of the types of partnerships which takes values from zero to seven. This variable was found to be insignificant in all specifications, inclusion did not affect our other conclusions and therefore we deleted it from our preferred model to conserve degrees of freedom.

[9] We also checked whether our results in the innovation performance equation change if we treat the decision to engage in partnerships as endogenous. We re-estimated equation (3) but

[TABLE 4 IS ABOUT HERE]

DISCUSSION AND CONCLUSIONS

Technology partnerships are inherently difficult to manage and as a result partnership instability rates are notoriously high. Our empirical results indicate that it is costly to encounter serious problems in technology partnerships. We find that for partnering firms going through a ‘bumpy road’ i.e. when badly performing technology partnerships induce unplanned outcomes as stoppage, delay or abandonment of innovation projects, the innovative performance is reduced substantially. In particular, in terms of generating new sales through new products experiencing a mal-functioning of technology partnerships is very costly. As a consequence, we think that firms have an incentive to counter such problems effectively.

Our results indicate that firms may pursue several strategies to reduce the likelihood of a ‘bumpy road’ in their partnerships. First, we find that firms that persistently rely on a product focus innovation strategy through developing new products, new markets and improving product quality face better chances in dealing with a ‘bumpy road.’ A strategy based on the exploration of these new opportunities, where firms persistently engage in joint innovation projects, rather than jointly exploiting cost efficiencies, lowers the probability of inter-organizational mal-functioning. As discussed in the above, persistent product and market innovators, are more successful in avoiding partnership problems because they face less uncertainty regarding both the goals of an alliance and the appropriate partnership

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instead of the actual cooperation variable, we used the predicted values from equation (2). The results are similar to those we report in Table 4. The coefficient on ‘bumpy road’ variable becomes somewhat smaller, but is still significant at the conventional levels.

candidate. In addition, firms with an innovative reputation, are desirable partners for technology partnerships (Stuart, Hoang and Hybels, 1999) and this reputation limits the potential frictions in technology partnerships. This result for the effect of a persistent innovation strategy, as a signal of consistency to partners, also indicates that it is important to avoid changing the firm's priorities in order to prevent partnership malfunctioning.

Second, we find that generating a diverse portfolio of partnerships may be helpful in obtaining the required experience in dealing with partners. Our results corroborate existing field research that has pointed out that firm's first-hand experience with partnerships and firm's ability to learn from its experience helps it avoid pitfalls in future partnerships (Lhuillery and Pfister, 2009; Kale et al., 2002). In particular, our results indicate that firms with links to a diverse group of other firms are confronted with a much lower incidence of problematic partnership outcomes. This relevance of the diversity of partnerships can be linked to attempts of firms to avoid the pitfalls of local search constraints (Rosenkopf and Nerkar, 2001). A diversity of partnerships gives access to a range of tacit skills, many of which are related to the technological capabilities and knowledge sources of these partners (Kogut and Zander, 1992; Lim, 2004). Firms that operate in a context of diverse contacts are more likely to benefit from an exposure to different ideas, varied experiences and a range of events through which they develop a more elaborate knowledge base on how to successfully manage their technology partnerships. Our findings suggest it is necessary to distinguish between the benefits of a current diverse portfolio and a diverse portfolio established in the past. We find that the current management of a diverse portfolio does not affect the probability of experiencing partnership malfunctioning. The learning experience materializes when a diverse portfolio was established some time ago. If some time has elapsed since the experience of a diverse partnership portfolio, capabilities can be generated that are instrumental for the effectiveness of future technology partnerships. However, these learning advantages have not yet materialized when the current portfolio of partnerships is very diverse. In particular, one may expect that if the current portfolio consists of a wide variety of different types of partnerships the management of this portfolio becomes more troublesome which may increase the probability of a `bumpy road.'

Third, the more firms are able to avoid 'bumpy roads' the higher their future innovative performance. As also established by Spender (2007) and Zahra and George (2002), firms with a higher diversity in their partnerships portfolio gradually develop skills that enable them to improve their ability to absorb valuable information from outside sources which we interpret as an ability to avoid mal-functioning in their partnership formation. The better organized the portfolio of partnerships, in the sense of avoiding troublesome partnerships, the better firms are at leveraging their newly acquired skills into new innovative activities that improve their innovative performance.

Interestingly, these results for the technology partnering behavior of firms resonate the findings of a classical study on the difference between successful and unsuccessful innovators (Rothwell, Freeman, Horsley, Jervis, Robertson, and Townsend, 1974). Similar to our findings on the 'bumpy road' of technology partnerships and their role in the innovation performance of firms, Rothwell et al. (1974) found, amongst other things, that firms with a persistent innovation strategy and a more extensive use of outside resources were more successful innovators than firms that scored lower on these characteristics. In the current world, where innovation is much more embedded in inter-firm technology partnerships, our findings illustrate that a diversity of outside technological resources through a seasoned and diverse portfolio of partnerships, in the context of a product focused innovation strategy, is crucial if firms attempt to minimize the effects of malfunctioning technology partnerships.

Limitations and future research

CIS follows a long tradition of Yale and SPRU innovation surveys by collecting a large amount of primary information on firms' innovative strategies. The advantage of CIS compared to other surveys is that it is a large-scale survey that does the sampling and data collection in a rather rigorous way (in many countries it is administered by the national statistical bureaus) and that it covers in a representative way most of the ISIC 3 sectors and firms of different size classes. While offering researchers interesting insights into firm's innovation process, a large-scale database like CIS has a number of limitations. First, it puts a constraint on the researcher in terms of the measures that can be used. Some fine-grained information, for instance, about firms' capabilities and the process that firms go through while organizing their partnerships, is not available. As pointed out earlier, one limitation of our framework is that we have no information on the relative importance of firms' individual collaborations within their portfolio of partnerships. Information on the number of ties of each type is also not available. Second, although CIS is conducted on a bi-annual basis, some questions do not belong to the 'core questionnaire' and thus are rotated or deleted from one survey to another. In our study we worked with some questions that are rotated. While it did not hamper our ability to trace firms across a number of years, it did put limitations to our ability to construct a proper panel and control for firm-specific effects.

In this paper we documented the benefits of persistent innovation strategies for alliance outcomes. Such persistency (as state dependence) can be due to various reasons such as resource needs, governance preferences, inertia and habit, path-dependency or the 'remediableness criterion' as discussed by Willamson (1996). A proper investigation of why persistence in a firm's innovation strategies arises in the first place is beyond the scope of this paper and is left for further research. Another interesting avenue for future research is a further investigation of the bi-directional link between firm's partnership capabilities and the performance of its technological partnerships. Initial exploratory research shows that some capabilities are more important than others and that firms can enhance partnership performance through development of particular partnership capabilities, which may act as a mediator between partnership experience and partnership performance (Zollo and Winter, 2002; Heimeriks and Duysters, 2007). A somewhat related avenue is the (mediating) effect of organizational competencies and specific managerial practices on firm's partnership performance. In our framework we highlighted the benefits of pursuing certain firm-level innovation strategies to reduce the probability of partnership-malfunctioning, yet a better understanding of the interplay between organizational and strategic aspects may be needed.

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Table 1 Descriptive statistics and construction of variables

	Variable name	Definition	Mean	S.D.
1	Bumpy road (*Bumpyroad*)	1 if a firm experienced mal-functioning in R&D technology partnerships which lead to one or more innovation projects stopped, seriously delayed or not started; else 0	0.05	0.21
2	Consistent product focus (*Prod_focus*)	Product of the sum of scores for 1996 and 1998 on the importance of four categories of innovation objectives, relating to new products and markets and products quality.	12.15	11.13
3	Consistent cost focus (*Cost_focus*)	Product of the sum of scores for 1996 and 1998 on the importance of six categories of objectives, including efficiency in production processes, labor, materials and the use of energy.	29.97	37.21
4	Partnership portfolio diversity (*Div*)	Blau's index of heterogeneity, see description in text	0.89	0.25
5	R&D intensity (*Rdint*)	Total internal innovation expenditures as a share of sales	0.04	1.26
6	Consistent vertical cooperation (*Coop_vert*)	1 if a firm reported engagement in technology partnerships with customers and/or suppliers but not competitors both in 1996 and 1998; else 0	0.04	0.21
7	Consistent horizontal cooperation (*Coop_hor*)	1 if a firm reported engagement in technology partnerships with competitors but not customers and suppliers both in 1996 and 1998; else 0	0.01	0.06
8	Consistent mixed cooperation (*Coop_mix*)	1 if a firm reported engagement in technology partnerships with customers and/or suppliers and competitors both in 1996 and 1998; else 0	0.01	0.11
9	Cooperation (*Cooperation*)	1 if a firm reported engagement in technology partnerships, else 0	0.22	0.42
10	Firm size (*Size*)	Logarithm of number of employees	4.37	1.18
11	Infrastructure (*Infra*)	1 if a firm reported engagement in cooperation with consultants and/or TNO, else 0	0.11	0.32
12	University cooperation (*Univ*)	1 if a firm reported engagement in cooperation with universities; else 0	0.07	0.26
13	Competition index (*Comp*)	constructed at the 2-digit industry level as a sum of scores on six dimensions corresponding to Porter's taxonomy	46.7	2.91
14	Incoming knowledge flows from industry & non-industry partners (*Spil*)	Sum of scores of importance of information received from customers, suppliers, competitors for firm's innovative activities	6.03	3.75
15	Incoming knowledge flows from public sources (*Pubspil*)	Sum of scores of importance of information received from patents, conferences, and publications competitors for firm's innovative activities	2.85	2.21

Table 1 Continued

16	Organizational constraints related to organization rigidities (*Hamp*$_8$)	Sum of scores on the following responses: Innovation project did not start, was abandoned or delayed due to short of qualified staff; due to short of knowledge; rigid organization	0.55	1.04
17	Organizational constraints related to costs (*Hamp*$_9$)	Sum of scores on the following responses: Innovation project did not start was abandoned or delayed due to short of financing; due to high costs	0.32	0.69
18	Organizational constraints related to risk (*Hamp*$_{10}$)	Sum of scores on the following responses: Innovation project did not start, was abandoned or delayed due to economic risks; due to uncertain markets	0.46	0.86
19	Domestic firm (*Domfirm*)	1 if the headquarters of the firm are located in the Netherlands, else 0	0.75	0.43
20	Part of a group (*Domgroup*)	1 if a firm is a part of a domestic corporate group, else 0	0.74	0.44
21	Patent (*Patent*)	1 if a firm reports to have patents, else 0	0.17	0.37

Table 2 Probit model (selection equation) for the technology cooperation decision

Dependent variable: *Cooperation*	First-stage model for Model 1	First-stage model for Model 2
Spil	0.05*** (0.01)	0.05*** (0.01)
Pubspil	0.00 (0.01)	0.00 (0.01)
Size	0.20*** (0.03)	0.20*** (0.03)
Rdint	0.01*** (0.00)	0.01*** (0.00)
Domfirm	0.06 (0.06)	0.05 (0.06)
Domgroup	0.10 (0.07)	0.10 (0.07)
Patent	0.24*** (0.09)	0.26*** (0.09)
$Hamp_8$	0.01 (0.03)	0.02 (0.03)
$Hamp_9$	0.06 (0.05)	0.05 (0.05)
$Hamp_{10}$	0.08*** (0.03)	0.09*** (0.03)
Industry dummies	Included	Included
N firms	2839	2839
Censored observations	2210	2210
Uncensored observations	629	629

Notes: Robust standard errors are in parentheses.
*** Indicates significance at 1%, ** at 5%, * at 10% level.

Table 3 Probit model for partnership mal-functioning

Dependent variable: *Bumpy road*$_t$	Second-stage model	
	Model 1 (with industry competition variable)	Model 2 (with industry dummies)
Prod_focus	-0.01*** (0.00)	-0.02*** (0.00)
Cost_focus	-0.00 (0.01)	-0.00 (0.00)
Div	0.13 (0.14)	0.16 (0.16)
Div$_{t-1}$	-0.41*** (0.14)	-0.41*** (0.14)
Rdint	-0.03*** (0.01)	-0.04*** (0.01)
Coop_vert	-0.26*** (0.09)	-0.26** (0.11)
Coop_hor	-0.11 (0.25)	-0.10 (0.26)
Coop_mix	-0.08 (0.16)	-0.06 (0.17)
Firm size	-0.16*** (0.04)	-0.14*** (0.05)
Infra	0.16 (0.13)	0.18 (0.15)
Univ	0.01 (0.14)	0.03 (0.17)
Comp	0.07*** (0.02)	
Industry dummies		Included
Correlation between equations (ρ)	-0.87 (0.07)	-0.82 (0.11)
Wald test of independent equations (p-value)	14.97 (0.00)	
N-firms	629	629
Log likelihood	-1536.62	-1543.85

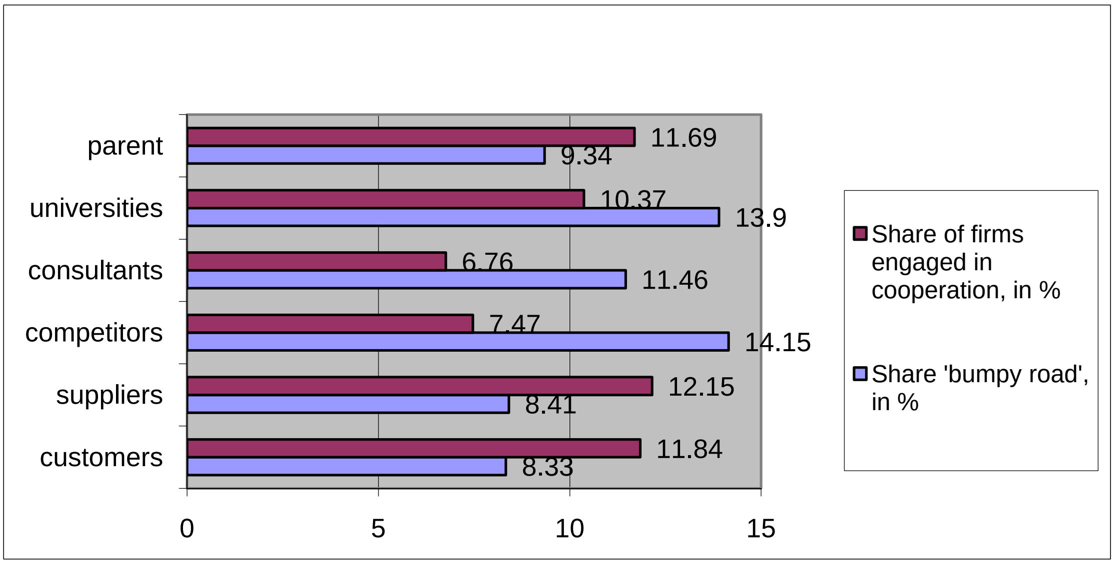
Notes: Robust standard errors are in parentheses.
*** Indicates significance at 1%, ** at 5%, * at 10% level.

Table 4 Innovative performance effects of 'bumpy road'

Dependent variable: *Newsales*$_{t+1}$	Performance model
$\hat{Y}$	-1.41** (0.71)
Cooperation	0.11*** (0.04)
Rdint	1.14 (1.30)
Size	0.08 (0.08)
Pubspil	0.06** (0.03)
Foreign MNE	0.17 (0.23)
Domgroup	-0.06 (0.21)
Industry dummies	Included
Location dummies	Included
R2	0.13
N firms	944

Notes: Robust standard errors are in parentheses.
*** Indicates significance at 1%, ** at 5%, * at 10% level.
All independent variables are for 1998 except for the industry and location dummies.

Appendix A **Propensity for cooperation and failure rates by type of partner**



Appendix B

Table B1, Correlations ‘bumpy road’ model

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	1.00																				
2	0.13	1.00																			
3	0.12	0.54	1.00																		
4	-0.07	-0.25	0.14	1.00																	
5	-0.07	0.13	-0.07	0.17	1.00																
6	-0.00	-0.02	-0.01	-0.07	0.01	1.00															
7	0.03	0.17	0.10	-0.29	-0.25	-0.00	1.00														
8	0.04	0.01	0.03	-0.13	-0.10	-0.00	-0.01	1.00													
9	0.05	0.12	0.07	-0.06	-0.03	-0.00	-0.02	-0.01	1.00												
10	0.05	0.19	0.21	-0.11	-0.12	0.01	0.09	0.05	0.15	1.00											
11	0.09	0.16	0.18	-0.10	-0.21	-0.00	0.20	0.10	0.20	0.24	1.00										
12	0.07	0.16	0.14	-0.11	-0.11	0.00	0.12	0.00	0.29	0.22	0.59	1.00									
13	-0.01	-0.20	-0.08	0.06	0.02	-0.02	-0.05	0.01	-0.03	0.04	-0.02	-0.05	1.00								
14	0.13	0.28	0.24	-0.36	-0.15	0.01	0.27	0.05	0.32	0.27	0.28	0.30	-0.07	1.00							
15	0.08	0.34	0.33	-0.11	-0.13	0.01	0.13	0.01	0.11	0.24	0.31	0.29	-0.06	0.22	1.00						
16	0.09	0.27	0.28	-0.06	-0.06	-0.01	0.10	0.02	0.08	0.14	0.18	0.20	-0.09	0.13	0.56	1.00					
17	0.05	0.17	0.09	-0.08	-0.12	0.01	0.09	-0.01	0.10	0.15	0.15	0.17	-0.08	0.15	0.20	0.15	1.00				
18	0.12	0.14	0.11	-0.06	-0.09	0.03	0.10	-0.01	0.12	0.05	0.14	0.18	-0.10	0.10	0.19	0.18	0.43	1.00			
19	0.13	0.21	0.16	-0.09	-0.12	0.02	0.11	0.02	0.11	0.12	0.18	0.18	-0.11	0.15	0.25	0.24	0.46	0.62	1.00		
20	0.02	-0.10	-0.09	0.07	0.07	0.01	-0.02	0.02	-0.01	-0.16	-0.07	-0.05	0.05	-0.07	-0.14	-0.04	-0.08	-0.03	-0.06	1.00	
21	0.03	0.09	0.08	-0.05	-0.05	0.01	0.02	0.03	0.02	0.23	0.04	0.03	0.03	0.10	0.13	0.06	0.07	0.03	0.05	-0.13	1.00
22	0.08	0.29	0.19	-0.11	-0.12	-0.00	0.11	0.06	0.11	0.20	0.18	0.18	-0.10	0.18	0.23	0.22	0.16	0.15	0.22	-0.15	0.10

(1) ‘Bumpy road’, (2) Consistent product focus, (3) Consistent cost focus, (4) Portfolio diversity year t, (5) Portfolio diversity year (t-1), (6) R&D intensity, (7) Consistent vertical, (8) Consistent horizontal, (9) Consistent mixed, (10) Firm size, (11) Infrastructure, (12) University cooperation, (13) Competition index, (14) Cooperation, (15) Incoming knowledge flows industry & non-industry, (16) Incoming knowledge flows public, (17) Organizational constraints, (18) Cost constraints, (19) Risk constraints, (20) Domestic firm, (21) Part of a group, (22) Patent.

Table B2, Correlations innovation performance model

	1	2	3	4	5	6	7
1	1.00						
2	-0.22	1.00					
3	0.14	-0.48	1.00				
4	0.21	-0.26	0.31	1.00			
5	0.12	-0.22	0.09	0.16	1.00		
6	0.08	-0.15	0.16	0.04	0.02	1.00	
7	0.05	0.08	-0.02	0.01	0.01	-0.70	1.00
8	0.15	-0.23	0.20	0.29	0.11	-0.06	0.01

(1) New sales, (2) Bumpy road (fitted), (3) Firm size, (4) Cooperation, (5) R&D intensity, (6) Foreign MNE, (7) Domestic group, (8) Incoming spillovers

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